

AD-A192 813

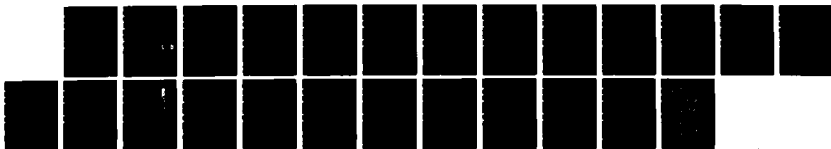
ELECTROCHEMISTRY AT VERY HIGH POTENTIALS: OXIDATION OF  
THE RARE GASES AND (U) UTAH UNIV SALT LAKE CITY DEPT  
OF CHEMISTRY S PONS ET AL 30 JUL 86 TR-62

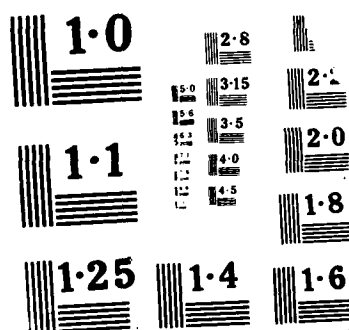
1/1

UNCLASSIFIED

F/G 7/2

NL





AD-A192 813

DTIC FILE COPY

OFFICE OF NAVAL RESEARCH

Contract N00014-83-K-0470-P00003

Task No. NR 359-718

TECHNICAL REPORT # 62

Electrochemistry at Very High Potentials: Oxidation of the Rare Gases  
and Other Gases in Non-Aqueous Solvents at Ultramicroelectrodes

By

Stanley Pons, T. Dibble, S. Bandyopadhyay, J. Ghoroghchian  
J. Smith, F. Sarfarazi, M. Fleischmann

Prepared for Publication in  
Journal of Physical Chemistry

University of Utah  
Department of Chemistry  
Salt Lake City, Utah 84112

July 30, 1986

Reproduction in whole or in part is permitted for  
any purpose of the United States Government.

This document has been approved for public release  
and sale; its distribution is unlimited.

DTIC  
ELECTE  
APR 13 1988  
S D  
a H

89 1 1 99

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 62	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Electrochemistry at Very High Potentials: Oxidation of the Rare Gases and Other Gases in Non- Aqueous Solvents at Ultramicroelectrodes		5. TYPE OF REPORT & PERIOD COVERED Technical Report # 62
7. AUTHOR(s) Stanley Pons, T. Dibble, S. Bandyopadhyay, J. Ghoroghchian, J. Smith, F. Sarfarazi, M. Fleischmann		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Utah Department of Chemistry Salt Lake City, UT 84112		8. CONTRACT OR GRANT NUMBER(s) N00014-83-K-0470-P0003
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Chemistry Program - Chemistry Code 472 Arlington, Virginia 22217		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task No. NR 359-718
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE July 30, 1986
		13. NUMBER OF PAGES
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) This document has been approved for public release and sale; its distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Ultramicroelectrodes, Rare Gases		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Oxidation of species with very high ionization potentials can be studied; oxidation of some of the rare gases and oxygen is reported in this work.		

*J. Phys. Chem.*

ELECTROCHEMISTRY AT VERY HIGH POTENTIALS:  
OXIDATION OF THE RARE GASES AND OTHER GASES IN NON-AQUEOUS  
SOLVENTS AT ULTRAMICROELECTRODES.

Timothy Dibble, Saibal Bandyopadhyay,  
Jamal Ghoroghchian, Jerry J. Smith, Fereshteh Sarfarazi,  
Martin Fleischmann\*\* and Stanley Pons\*

\*Department of Chemistry

University of Utah

Salt Lake City, UT 84112

\*\*Department of Chemistry

The University

Southampton, Hants. SO9 5NH

ENGLAND

\*To whom correspondence should be addressed.

# ABSTRACT

Ultramicroelectrodes may be used in solvents containing little or no purposely added supporting electrolyte. Under these conditions, the accessible potential range is considerably extended. Oxidation of species with very high ionization potentials can be studied; oxidation of some of the rare gases and oxygen is reported in this work.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

## INTRODUCTION

The accessible potential region in a conventional electrochemical experiment is limited by the oxidation or reduction of the solvent or supporting electrolyte. Under ideal conditions, at room temperature, this window can range from something over +3V vs. Ag/Ag<sup>-</sup> (e.g. acetonitrile, SO<sub>2</sub> solvents), to slightly greater than -3V vs. Ag/Ag<sup>-</sup> (e.g. acetonitrile, ammonia, tetrahydrofuran solvents). It is thus impossible to study the redox reactions of species with very low electron affinities or high ionization potentials by ordinary electrochemical methods. It has been demonstrated recently, however, that by reducing the electrode dimensions to very small values, the quantity of supporting electrolyte necessary to develop the electrical double layer can be reduced to low levels (1). It has thus been possible to study electrode reactions in highly resistive media; these include the oxidation of ferrocene in acetonitrile without purposely added supporting electrolyte, oxidation of chromium hexacarbonyl in pure dichloromethane, oxidation of aromatic hydrocarbons in pure benzene, oxidation ferrocene in pure acetone down to -95°C (2), and oxidations in low temperature solid-solution eutectic mixtures and glasses of acetonitrile (3), to mention a few. Elimination of the ionic supporting electrolyte can extend the accessible potential range in those cases where it is the limiting redox reaction. One such example is oxidation in acetonitrile. The oxidation of the anion of all tested supporting electrolytes in this solvent will occur at potentials less than about 3V vs. Ag/Ag<sup>-</sup>. We have recently demonstrated (4) that voltammetric data can be obtained at much higher oxidation potentials (c.a. 6V vs. Ag/Ag<sup>-</sup>). In this high energy region, it was possible to observe steady state voltammetric behavior for compounds with vertical ionization

potentials as high as 12.70 V. These included n-heptane, cyclopropane, n-pentane, n-butane, and methane. At these high accessible potentials, we have found that it is possible to observe the oxidation of rare gas substrates. Homogeneous electron transfer reactions involving the rare gases and oxygen were first reported by Bartlett et al (5); they have not been investigated by electrochemical methods.

### EXPERIMENTAL

Ring ultramicroelectrodes (Figure 1) are conveniently prepared by (a) coating the inner surface of fine capillaries with metal by vapor deposition or reduction of metal screen printing inks applied to those surfaces, followed by controlled collapsing of the capillary around a glass fiber; or conversely, (b) using the same procedures to deposit the metal on a fine glass or quartz fiber, and collapsing a glass tube around it; or mounting the fiber in a glass tube with epoxy resin. The gold ring electrode used in this work was 20  $\mu\text{m}$  in diameter and had an average thickness of 7500 Å. The platinum microdisk electrode was constructed by sealing a 0.6  $\mu\text{m}$  diameter wire in a glass tube, and then cutting perpendicular to the axis of the tube to expose the disk. The auxiliary pseudo-reference electrode was a silver/silver ion assembly mounted in a glass tube which contained a solvent wetted stopcock and a Luggin capillary arrangement. The tip of the Luggin was placed about 1 mm from the tip of the ultramicroelectrode. The cell was a small flask designed to hold 5 mL of solution. The electrodes were mounted through ground glass joints to their working positions. The cell was cleaned in hot acid solution (sulfuric nitric 1/1 V/V), rinsed in triply distilled water, and vacuum dried at 110°C.

The acetonitrile solvent was used as received (Burdick and Jackson, Distilled in Glass, 0.005% nominal water content). Oxygen, methane, and nitrogen were obtained from Matheson (research grade) and were used as received. The other gases used were from Ideal Gas Products (research grade), and were also used as received. These included xenon, carbon monoxide, krypton, and argon.

The cell assembly was mounted on steel clamps inside a 2 ft<sup>3</sup> 3/8" thick aluminum Faraday cage. Connection through the cage was made with triaxial bulkhead connectors. All cables used were triaxial, and were rigidly mounted to prevent noise current generation by mechanical friction between the insulator and conductors in the cable.

The electrode potential difference was maintained by waveform generator (Hi Tek Instruments PPR1) added to a battery. Currents were measured on a Keithley 619 picoammeter, and the polarization curves were plotted manually or on a Hewlett Packard 7015 x-y recorder.

## RESULTS AND DISCUSSION

Polarization curves for compounds with very high ionization potentials were obtained by the methods described. A polarization for one example, krypton, is shown in Figure 2. In all cases studied, the height of the limiting current plateau is dependent on the partial pressure of the electroactive gas (see also Table I). Currents observed then are not due to discharge ionization or corona discharge into the dielectric solvent system used in the experiments. This clearly indicates that conventional electrochemical reactions may be carried out at very high potentials in dielectric solvent media and that the current is due solely to the electron transfer reaction. In addition, the  $E_{1/2}$  values are

dependent on the type of is present. Previous work (3) showed that at very high potentials, a surface polymeric film is formed on the electrode which passivates the electrode; the bulk electrolysis of the solvent is therefore prevented. This insulating film is, however, permeable to small molecules including the those investigated in this work.

Figure 3 is a plot of  $E_{1/2}$  vs.  $I_p$  for a number of simple compounds which have high vertical ionization potentials. The seven compounds on the right side of the Figure were analyzed in this work, while the hydrocarbon data on the left side represents previous work (6). It is noticed that for these molecules with very high ionization potentials, the effect of increases in  $I_p$  on  $E_{1/2}$  is much smaller than for the compounds with smaller ionization potentials.

In the absence of secondary effects, such as large differences in the solvation energies of an oxidized and reduced form of a redox couple, a linear relation between the oxidation potential and the vertical ionization potential of an electroactive species is to be expected. For a simple redox process



we have

$$E_{\text{rev}}^{\theta} = -\frac{1}{nF} (\Delta G_R^{\theta}(\text{SOLVATION}) - \Delta G_O^{\theta}(\text{SOLVATION})) - \frac{I_p}{nF} - E_{\text{ref}}^{\theta}$$

where the term in brackets represents the change in free energy of solvation between the reduced and oxidized forms of the couple,  $n$  is the number of electrons exchanged per mole of reactant,  $F$  is the Faraday constant,  $I_p$  is the ionization potential, and  $E_{\text{ref}}^{\theta}$  is the standard potential of the reference electrode, which we will assume to be a constant value here. The same type of

relation will exist in non-standard states if the activities of the species are taken into account:

$$E_{\text{rev}} = E_{\text{rev}}^{\theta} - \frac{RT}{nF} \ln \frac{a_{\text{O}}^{\sigma}}{a_{\text{R}}^{\sigma}}$$

where  $a_{\text{O}}^{\sigma}$  and  $a_{\text{R}}^{\sigma}$  are the activities of the oxidized and reduced forms at the electrode surface, respectively. If the difference between the solvation energies of the reduced and oxidized forms is large, then  $E_{1/2}$  will be smaller than when the standard free energies of the two species are equal. One fact is immediately evident from Figure 3: the linear relation is obeyed quite well for the larger electroactive species: those which are on the order of, or larger than, the solvent molecule. Solvation of the larger species can only occur after there is solvent structure rearrangement or breaking: an endothermic process which ultimately reduces the total effect of the magnitude of the difference in the standard free energy of solvation of the two species. Smaller ions, however, show a considerable departure from linear behavior of  $E_{1/2}$  and  $I_p$  with slope unity: very small ions, having therefore a high charge density, are as expected more efficiently solvated into the solvent cage structure. The difference in the solvation energies of the neutral and oxidized species is large, reflecting the large change in size of the two species, and the half wave potential is greatly decreased.

Chemical reaction of the electrogenerated ion is most likely fast in the bulk solution, and in the case of the rare gases results in a regeneration of the starting material, at least to an appreciable extent. At a normal macroelectrode, this reaction would give rise to a catalytic current that is

higher than the expected uncomplicated diffusion limited current. At an ultramicroelectrode, mass transport is very high so that it is likely that most of the regeneration of starting material will take place at distances suitably distant from the working electrode so that the catalytic current will be minimized. This point was demonstrated by comparing the measured limiting current for a solution saturated with krypton with the value calculated from the relations derived previously (4) for the ring ultramicroelectrode. The values were found to be the same within estimated experimental error.

#### CONCLUSIONS

It is clear that a variety of new and interesting chemical systems may be investigated by taking advantage of the unusual properties of ultramicroelectrodes. High rates of mass transport, reduction of ohmic losses in solution, and low capacitive currents allow measurements to be made under conditions that heretofore have been considered futile. Highly energetic species exhibiting large size changes upon electron transfer may be studied electrochemically due to the great difference in solvation energies of the conjugate redox pair.

ACKNOWLEDGEMENTS

We thank the Office of Naval Research for support of this work.

## LITERATURE REFERENCES

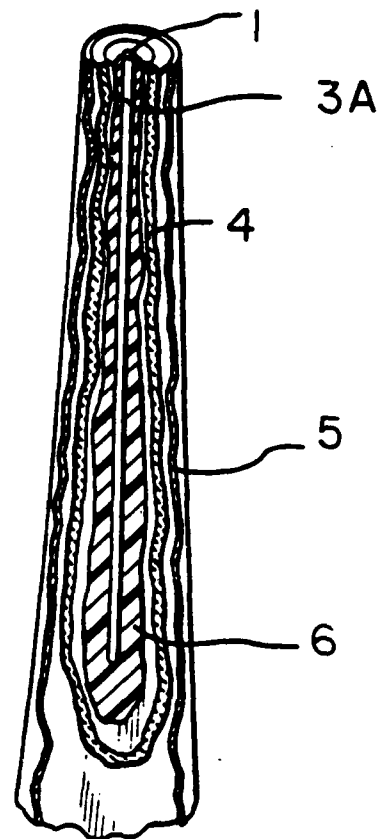
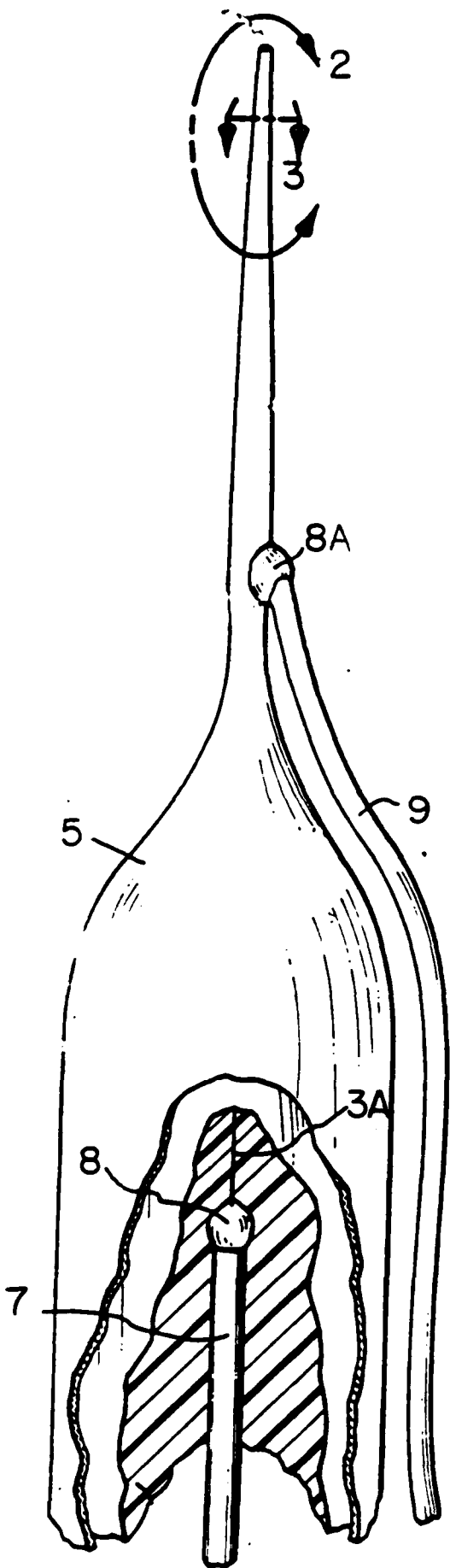
1. A.M. Bond, M. Fleischmann, J. Robinson, J. Electroanal. Chem. 168(1984)299.
2. A.M. Bond, M. Fleischmann, and J. Robinson, J. Electroanal. Chem. 180(1984)257.
3. J. Cassidy, S.B. Khoo, S. Pons, and M. Fleischmann, J. Phys. Chem. 89(1985)3933.
4. M. Fleischmann, S. Bandyopadhyay, and S. Pons, J. Phys. Chem. 89(1985)5537.
5. N.Bartlett and N.K. Jha in Noble Gas Compounds, H.H. Hyman, Ed., University of Chicago Press, Chicago and London, 1963, p. 23ff.
6. D. Clark, M. Fleischmann, and D. Pletcher, Chem. Eng. Techn. 44(1972)187 and references therein.

TABLE I. Limiting Current Values as a Function of the Gas Partial Pressure

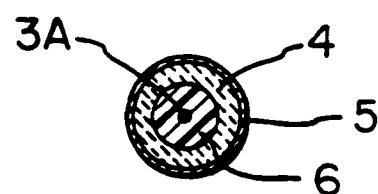
Reactant	Partial Pressure/atm	Limiting Current/nA
Krypton	1.09	1.2
	1.22	1.3
	1.78	2.0
	2.91	3.2
Oxygen	1.10	1.1
	1.90	2.0
	3.12	3.1
Carbon Monoxide	1.23	1.2
	2.64	2.6
	2.98	2.8
Xenon	1.00	1.1
	2.23	2.4
	3.13	3.4

### LEGENDS FOR THE FIGURES

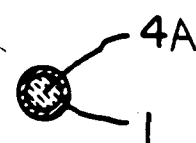
1. Ultramicroelectrode (gold ring) gas phase detector assembly. The microelectrode assembly (3A) in this case is constructed of a thin gold film (1) on a glass fiber (4A). The tip cross section (3) consists of the assembly (3A) sealed in a glass tube (4) coated with a thick metal film (5) with epoxy resin (6). (2) details the side view of the tip. A fine copper wire (9) is soldered to the metal film for external contact to the auxiliary/ reference electrode with lead solder (8A), while a similar connection is made to the microelectrode with another copper wire (7) with silver epoxy (8).
2. Polarization curve for the oxidation of krypton in acetonitrile solution containing no purposely added supporting electrolyte. Potential sweep rate was  $25 \text{ mV-s}^{-1}$ .
3. Plot of the vertical ionization potential for several small molecules vs. the measured half wave oxidation potential in acetonitrile solution at an ultramicroelectrode.



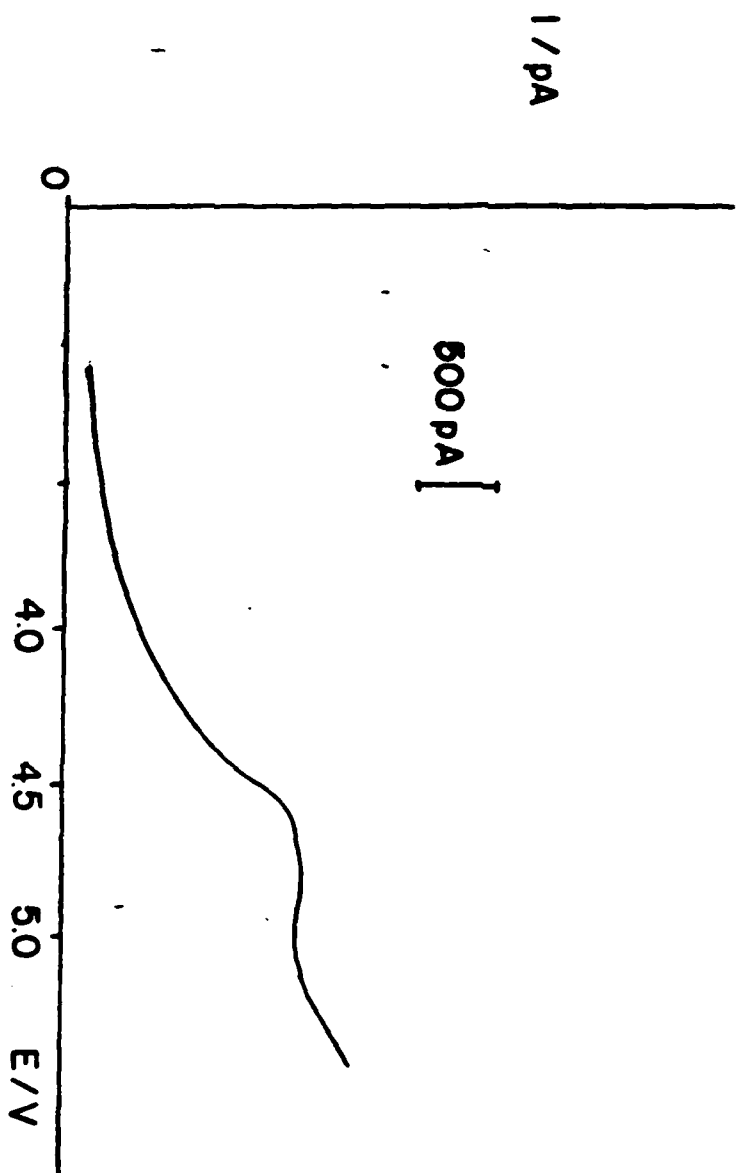
2

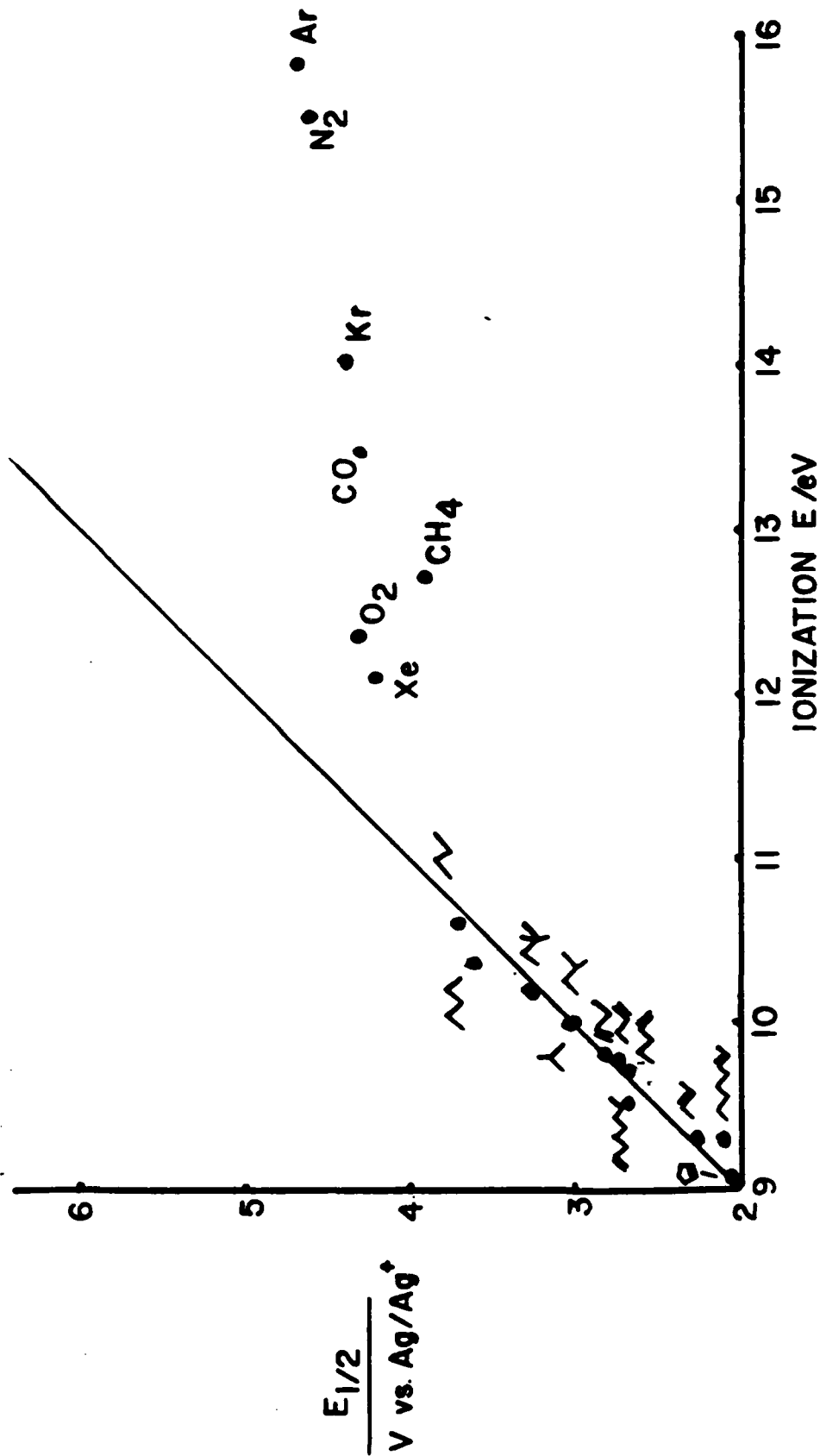


3



3A





DL/413/83/01  
GEN/413-2

TECHNICAL REPORT DISTRIBUTION LIST, GEN

	<u>No. Copies</u>		<u>No. Copies</u>
Office of Naval Research Attn: Code 413 800 N. Quincy Street Arlington, Virginia 22217	2	Dr. David Young Code 334 NORDA NSTL, Mississippi 39529	1
Dr. Bernard Douda Naval Weapons Support Center Code 5042 Crane, Indiana 47522	1	Naval Weapons Center Attn: Dr. Ron Atkins Chemistry Division China Lake, California 93555	1
Commander, Naval Air Systems Command Attn: Code 310C (H. Rosenwasser) Washington, D.C. 20360	1	Scientific Advisor Commandant of the Marine Corps Code RD-1 Washington, D.C. 20380	1
Naval Civil Engineering Laboratory Attn: Dr. R. W. Drisko Port Hueneme, California 93401	1	U.S. Army Research Office Attn: CRD-AA-IP P.O. Box 12211 Research Triangle Park, NC 27709	1
Defense Technical Information Center Building 5, Cameron Station Alexandria, Virginia 22314	12	Mr. John Boyle Materials Branch Naval Ship Engineering Center Philadelphia, Pennsylvania 19110	1
DTNSRDC Attn: Dr. G. Bosmajian Applied Chemistry Division Annapolis, Maryland 21401	1	Naval Ocean Systems Center Attn: Dr. S. Yamamoto Marine Sciences Division San Diego, California 91232	1
Dr. William Tolles Superintendent Chemistry Division, Code 6100 Naval Research Laboratory Washington, D.C. 20375	1		

ABSTRACTS DISTRIBUTION LIST, 359/627

Dr. Paul Delahay  
Department of Chemistry  
New York University  
New York, New York 10003

Dr. P. J. Hendra  
Department of Chemistry  
University of Southampton  
Southampton SO9 5NH  
United Kingdom

Dr. J. Driscoll  
Lockheed Palo Alto Research  
Laboratory  
3251 Hanover Street  
Palo Alto, California 94304

Dr. D. N. Bennion  
Department of Chemical Engineering  
Brigham Young University  
Provo, Utah 84602

Dr. R. A. Marcus  
Department of Chemistry  
California Institute of Technology  
Pasadena, California 91125

Dr. J. J. Auborn  
Bell Laboratories  
Murray Hill, New Jersey 07974

Dr. Joseph Singer, Code 302-1  
NASA-Lewis  
21000 Brookpark Road  
Cleveland, Ohio 44135

Dr. P. P. Schmidt  
Department of Chemistry  
Oakland University  
Rochester, Michigan 48063

Dr. Manfred Breiter  
Institut für Technische Elektrochemie  
Technischen Universität Wien  
9 Getreidemarkt, 1160 Wien  
AUSTRIA

Dr. E. Yeager  
Department of Chemistry  
Case Western Reserve University  
Cleveland, Ohio 44106

Dr. C. E. Mueller  
The Electrochemistry Branch  
Naval Surface Weapons Center  
White Oak Laboratory  
Silver Spring, Maryland 20910

Dr. Sam Perone  
Chemistry & Materials  
Science Department  
Lawrence Livermore National Laboratory  
Livermore, California 94550

Dr. Royce W. Murray  
Department of Chemistry  
University of North Carolina  
Chapel Hill, North Carolina 27514

Dr. B. Brummer  
EIC Incorporated  
111 Downey Street  
Norwood, Massachusetts 02062

Dr. Adam Heller  
Bell Laboratories  
Murray Hill, New Jersey 07974

Dr. A. B. Ellis  
Chemistry Department  
University of Wisconsin  
Madison, Wisconsin 53706

Library  
Duracell, Inc.  
Burlington, Massachusetts 01803

Electrochimica Corporation  
20 Kelly Court  
Menlo Park, California 94025-1418

ABSTRACTS DISTRIBUTION LIST, 359/627

Dr. M. Wrighton  
Chemistry Department  
Massachusetts Institute  
of Technology  
Cambridge, Massachusetts 02139

Dr. B. Stanley Pons  
Department of Chemistry  
University of Utah  
Salt Lake City, Utah 84112

Donald E. Mains  
Naval Weapons Support Center  
Electrochemical Power Sources Division  
Crane, Indiana 47522

S. Ruby  
DOE (STOR)  
Room 5E036 Forrestal Bldg., CE-14  
Washington, D.C. 20595

Dr. A. J. Bard  
Department of Chemistry  
University of Texas  
Austin, Texas 78712

Dr. Janet Osteryoung  
Department of Chemistry  
State University of New York  
Buffalo, New York 14214

Dr. Donald W. Ernst  
Naval Surface Weapons Center  
Code R-33  
White Oak Laboratory  
Silver Spring, Maryland 20910

Mr. James R. Moden  
Naval Underwater Systems Center  
Code 3632  
Newport, Rhode Island 02840

Dr. Bernard Spielvogel  
U.S. Army Research Office  
P.O. Box 12211  
Research Triangle Park, NC 27709

Dr. Aaron Fletcher  
Naval Weapons Center  
Code 3852  
China Lake, California 93555

Dr. M. M. Nicholson  
Electronics Research Center  
Rockwell International  
3370 Miraloma Avenue  
Anaheim, California

Dr. Michael J. Weaver  
Department of Chemistry  
Purdue University  
West Lafayette, Indiana 47907

Dr. R. David Rauh  
EIC Laboratories, Inc.  
111 Downey Street  
Norwood, Massachusetts 02062

Dr. Aaron Wold  
Department of Chemistry  
Brown University  
Providence, Rhode Island 02192

Dr. Martin Fleischmann  
Department of Chemistry  
University of Southampton  
Southampton SO9 5NH ENGLAND

Dr. R. A. Osteryoung  
Department of Chemistry  
State University of New York  
Buffalo, New York 14214

Dr. John Wilkes  
Air Force Office of Scientific  
Research  
Bolling AFB  
Washington, D.C. 20332

Dr. R. Nowak  
Naval Research Laboratory  
Code 6171  
Washington, D.C. 20375

Dr. D. F. Shriver  
Department of Chemistry  
Northwestern University  
Evanston, Illinois 60201

ABSTRACTS DISTRIBUTION LIST, 359/627

Dr. Hector D. Abruna  
Department of Chemistry  
Cornell University  
Ithaca, New York 14853

Dr. A. B. P. Lever  
Chemistry Department  
York University  
Downsview, Ontario M3J1P3

Dr. Stanislaw Szpak  
Naval Ocean Systems Center  
Code 633, Bayside  
San Diego, California 95152

Dr. Gregory Farrington  
Department of Materials Science  
and Engineering  
University of Pennsylvania  
Philadelphia, Pennsylvania 19104

M. L. Robertson  
Manager, Electrochemical  
and Power Sources Division  
Naval Weapons Support Center  
Crane, Indiana 47522

Dr. T. Marks  
Department of Chemistry  
Northwestern University  
Evanston, Illinois 60201

Dr. Micha Tomkiewicz  
Department of Physics  
Brooklyn College  
Brooklyn, New York 11210

Dr. Lesser Blum  
Department of Physics  
University of Puerto Rico  
Rio Piedras, Puerto Rico 00931

Dr. Joseph Gordon, II  
IBM Corporation  
5600 Cottle Road  
San Jose, California 95193

Dr. Nathan Lewis  
Department of Chemistry  
Stanford University  
Stanford, California 94305

Dr. D. H. Whitmore  
Department of Materials Science  
Northwestern University  
Evanston, Illinois 60201

Dr. Alan Bewick  
Department of Chemistry  
The University of Southampton  
Southampton, SO9 5NH ENGLAND

Dr. E. Anderson  
NAVSEA-56Z33 NC #4  
2541 Jefferson Davis Highway  
Arlington, Virginia 20362

Dr. Bruce Dunn  
Department of Engineering &  
Applied Science  
University of California  
Los Angeles, California 90024

Dr. Elton Cairns  
Energy & Environment Division  
Lawrence Berkeley Laboratory  
University of California  
Berkeley, California 94720

Dr. Richard Pollard  
Department of Chemical Engineering  
University of Houston  
Houston, Texas 77004

Dr. M. Philpott  
IBM Corporation  
5600 Cottle Road  
San Jose, California 95193

Dr. Donald Sandstrom  
Boeing Aerospace Co.  
P.O. Box 3999  
Seattle, Washington 98124

Dr. Carl Kannewurf  
Department of Electrical Engineering  
and Computer Science  
Northwestern University  
Evanston, Illinois 60201

Dr. Joel Harris  
Department of Chemistry  
University of Utah  
Salt Lake City, Utah 84112

ABSTRACTS DISTRIBUTION LIST, 359/627

Dr. Robert Somoano  
Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California 91103

Dr. Johann A. Joebstl  
USA Mobility Equipment R&D Command  
DRDME-EC  
Fort Belvoir, Virginia 22060

Dr. Judith H. Ambrus  
NASA Headquarters  
M.S. RTS-6  
Washington, D.C. 20546

Dr. Albert R. Landgrebe  
U.S. Department of Energy  
M.S. 6B025 Forrestal Building  
Washington, D.C. 20595

Dr. J. J. Brophy  
Department of Physics  
University of Utah  
Salt Lake City, Utah 84112

Dr. Charles Martin  
Department of Chemistry  
Texas A&M University  
College Station, Texas 77843

Dr. H. Tachikawa  
Department of Chemistry  
Jackson State University  
Jackson, Mississippi 39217

Dr. Theodore Beck  
Electrochemical Technology Corp.  
3935 Leary Way N.W.  
Seattle, Washington 98107

Dr. Farrell Lytle  
Boeing Engineering and  
Construction Engineers  
P.O. Box 3707  
Seattle, Washington 98124

Dr. Robert Gotscholl  
U.S. Department of Energy  
MS G-226  
Washington, D.C. 20545

Dr. Edward Fletcher  
Department of Mechanical Engineering  
University of Minnesota  
Minneapolis, Minnesota 55455

Dr. John Fontanella  
Department of Physics  
U.S. Naval Academy  
Annapolis, Maryland 21402

Dr. Martha Greenblatt  
Department of Chemistry  
Rutgers University  
New Brunswick, New Jersey 08903

Dr. John Wasson  
Syntheco, Inc.  
Rte 6 - Industrial Pike Road  
Gastonia, North Carolina 28052

Dr. Walter Roth  
Department of Physics  
State University of New York  
Albany, New York 12222

Dr. Anthony Sammells  
Eltron Research Inc.  
4260 Westbrook Drive, Suite 111  
Aurora, Illinois 60505

Dr. C. A. Angell  
Department of Chemistry  
Purdue University  
West Lafayette, Indiana 47907

Dr. Thomas Davis  
Polymer Science and Standards  
Division  
National Bureau of Standards  
Washington, D.C. 20234

Ms. Wendy Parkhurst  
Naval Surface Weapons Center R-33  
R-33  
Silver Spring, Maryland 20910

DL/413/83/01  
359/413-2

ABSTRACTS DISTRIBUTION LIST, 359/627

Dr. John Owen  
Department of Chemistry and  
Applied Chemistry  
University of Salford  
Salford M5 4WT ENGLAND

Dr. O. Stafsudd  
Department of Electrical Engineering  
University of California  
Los Angeles, California 90024

Dr. Boone Owens  
Department of Chemical Engineering  
and Materials Science  
University of Minnesota  
Minneapolis, Minnesota 55455

Dr. S. G. Greenbaum  
Department of Physics  
Hunter College of CUNY  
New York, New York 10021

Dr. J. O. Thomas  
University of Uppsala  
Institute of Chemistry  
Box 531  
S-751 21 Uppsala, Sweden

Dr. Menahem Anderman  
W.R. Grace & Co.  
Columbia, Maryland 20144

END

DATE

FILMED

DTIC

6-88